Natural Gas Liquids Extraction

May 1996

TABLE OF CONTENTS

CHEM SYSTEMS

L	EXE	ECUT	IVE SUMMARY	1
	Α.	INT	RODUCTION	1
	В.	CUF	RRENT COMMERCIAL TECHNOLOGY	3
		1.	Processing Requirements	3
		2.	NGL Extraction Technology	4
		3.	Economics	5
	C.	TEC	CHNOLOGY DEVELOPMENTS	10
	D.	MAF	RKET ANALYSIS	11
		1.	Natural Gas	11
		2.	Gas Liquids	15
11	CUI	RREN	NT COMMERCIAL TECHNOLOGY	18
	Α.	INTE	RODUCTION	18
		1.	Terminology	18
		2.	Sources of Natural Gas and Natural Gas Liquids	18
		3.	Uses of Natural Gas and Natural Gas Liquids	19
			(a) Sales Gas	19
			(b) Natural Gas Liquids (NGLs)	20
			(c) Ethane	21
			(d) Propane and Butane	21
			(e) Pentanes and Heavier Hydrocarbons	22
	В.	PRC	DCESSING REQUIREMENTS OF NATURAL GAS	23
		1.	Phase Envelopes	25
		2.	Sales Gas Quality Specifications	25
			(a) Transmission and Distribution	25
			(b) Power Stations	25
			(c) Feedstock	25
		3.	Implications for NGL Extraction	28
			(a) Maximum NGL Content of Sales Gas	28
			(b) Minimum NGL Content of Sales Gas	29
		4.	NGL Recovery, Blending and Inert Gas Injection and Removal	29

TABLE OF CONTENTS (Continued)

	5.	Water Removal	31	
		(a) Glycol Contacting	33	
		(b) Dry Desiccant Adsorption	33	
		(c) Hydrate Inhibitor Injection	33	
	6.	Acid Gas Treating	36	
	7.	Other Gas Processing Requirements	37	
	8.	Processing of Wellhead Fluids	37	
C.	NATURAL GAS LIQUID EXTRACTION PROCESSES			
	1.	Joule-Thomson Plants	40	
	2.	Mechanical Refrigeration Plants	44	
	3.	Turbo-Expander Plants	47	
	4.	Short Cycle Adsorption	51	
	5.	Lean Oil Absorption	54	
	6.	Impact of Available Gas Stream Pressure on Choice of		
		NGL Extraction Method	54	
	7.	Natural Gas Liquids Fractionation	57	
D.	ECO	DNOMICS	63	
	1.	Introduction	63	
	2.	Methodology		
	3.	Basis		
		(a) Raw Gas Stream	65	
		(b) Sales Gas Specifications	65	
		(c) Product Prices and Labor and Utility Costs	65	
	4.	Identification of Technically Suitable NGL Extraction Processes	66	
	5.	Capital Costs		
	6.	NGL Extraction Costs	70	
		(a) Shrinkage	70	
		(b) Capital Charges	72	
		(c) Processing Cash Costs	72	
		(d) Total Built-Up Production Cost	72	

TABLE OF CONTENTS (Continued)

Page

	7.	Revenues and Profits	73
			-
	8.	Calculation of Marginal Costs and Revenues	73
	9.	Optimum NGL Recovery Rate for the Base Case	73
	10.	Sensitivity Analysis	79
	11.	Ethane Extraction Economics	81
	12.	Conclusions	85
Е.	CO	NTRACTORS AND TECHNOLOGY SUPPLIERS	93
	1.	Engineering Companies	93
		(a) Major U.S. Engineering Companies	93
		(b) Smaller U.S. Engineering Companies	94
		(c) Other Companies	94
	2.	Technology Suppliers	94
		(a) NGL Recovery	94
		(b) Dehydration and Acid Gas Removal	94
TE	СНИС	OLOGY DEVELOPMENTS	95
А.	INT	RODUCTION	95
В.	PR	OPRIETARY PROCESSES	96
	1.	IFPEXOL Process	96
	2.	PETROFLUX Process	96
	3.	SELEXOL Process	101
	4.	HY-PRO Process	103
	5.	"Gas Sub-Cooled" Process	103

Ш

TABLE OF CONTENTS (Continued)

IV	MAF	RKET	ANALYSIS	106
	Α.	INTF	RODUCTION	106
	В.	GENERAL MARKET CHARACTERISTICS		
		1.	Natural Gas	106
		2.	Natural Gas Liquids	107
			(a) Ethane	107
			(b) Propane and Butane	107
			(c) Natural Gasoline/Condensate	109
	C.	GLO	BALOVERVIEW	110
		1.	Natural Gas	110
		2.	Natural Gas Liquids	114
	D.	NOR	RTH AMERICA	118
		1.	Natural Gas	118
			(a) Supply	118
			(b) Demand	118
		2.	Natural Gas Liquids	119
			(a) Supply	119
			(b) Demand	119
	E.	CEN	ITRAL AND SOUTH AMERICA	122
		1.	Natural Gas	122
			(a) Supply	122
			(b) Demand	122
		2.	Natural Gas Liquids	123
			(a) Supply	123
			(b) Demand	123

TABLE OF CONTENTS (Continued)

F.	WESTERN EUROPE			124
	1.	Natu	ural Gas	124
		(a)	Supply	124
		(b)	Demand	124
	2.	Natu	ural Gas Liquids	124
		(a)	Supply	124
		(b)	Demand	127
G.	CEN	ITRAI	L EUROPE	128
	1.	Natu	ural Gas	128
		(a)	Supply	128
		(b)	Demand	128
Н.	FORMER SOVIET UNION (FSU)			129
	1.	Natu	ural Gas	129
		(a)	Supply	129
		(b)	Demand	130
	2.	Natu	ural Gas Liquids	130
		(a)	Supply	130
		(b)	Demand	132
I.	MIDDLE EAST			
	1.	Natu	ural Gas	134
		(a)	Supply	134
		(b)	Demand	135
	2.	Natu	ural Gas Liquids	135
		(a)	Supply	135
		(b)	Demand	138

TABLE OF CONTENTS (Continued)

Page

J.	AFR	RICA	139	
	1.	Natural Gas	139	
		(a) Supply	139	
		(b) Demand	139	
	2.	Natural Gas Liquids	140	
		(a) Supply	140	
		(b) Demand	140	
K.	ASIA/AUSTRALIA			
	1.	Natural Gas	141	
		(a) Supply	141	
		(b) Demand	141	
	2.	Natural Gas Liquids	142	
		(a) Supply	142	
		(b) Demand	142	
L.	WO	RLDWIDE GAS PROCESSING	143	

APPENDIX

- A. DEFINITION OF TERMS IN SALES GAS SPECIFICATIONS
 - 1. Higher Heating Value (Alternative Term: Gross Calorific Value)
 - 2. Lower Heating Value (Alternative Term: Net Calorific Value)
 - 3. Wobbe Index
 - 4. Hydrocarbon Dew Point
 - 5. Water Dew Point

REFERENCES

GLOSSARY

BASIC TECHNICAL DATA FOR ENERGY AND HYDROCARBONS

TABLES

CHEM SYSTEMS

Table I.B.1	Cost of Service Variation with Plant Size and Gas	
	Composition	6
Table I.B.2	Example NGL Extraction Economics, USGC 1994/1995	7
Table I.C.1	Proprietary Developments in NGL Extraction Technology	10
Table I.D.1	Gas/Gas Liquids Processing Capacity and Production	15
Table II.A.1	Natural Gas Terminology	18
Table II.A.2	Natural Gas Compositions	19
Table II.A.3	Properties of Natural Gas Components	20
Table II.A.4	Uses of Natural Gas Components	21
Table II.B.1	Main Processing Requirements of Natural Gas	23
Table II.B.2	Typical Sales Gas Specifications for Transmission and	
	Distribution	27
Table II.B.3	Acid Gas Removal Methods	36
Table II.C.1	GPA Liquefied Petroleum Gas Specifications	59
Table II.C.2	Representative Quality Criteria for Ethane Streams	60
Table II.C.3	GPA Natural Gasoline Specifications and Test Methods	61
Table II.D.1	Product Prices, Labor and Utility Costs	66
Table II.D.2	Processes Analyzed to Establish Variation of Capital Cost	
	with Propane Recovery	69
Table II.D.3	Calculation of Shrinkage	71
Table II.D.4	Calculation of Processing Cash Cost	72
Table II.D.5	Cost of Production Estimate for NGL Extraction Plant	74
Table II.D.6	Example Calculation of Revenues and Profits	75
Table II.D.7	Calculation of Marginal Revenues and Costs	76
Table II.D.8	Raw Gas Compositions	79
Table II.D.9	Product Prices, Labor and Utility Costs	81
Table II.D.10	Optimum NGL Recovery Levels	82

TABLES (Continued)

Table II.D.11	Cost of Production Estimate for Ethane Extraction Plant	83
Table II.D.12	NGL Extraction Costs for Different Raw Gas Compositions	86
Table II.D.13	NGL Extraction Costs for Different Plant Capacities	87
Table IV.C.1	Global Natural Gas Demand Forecast	114
Table IV.C.2	Global LPG Supply/Demand for 1994	117
Table IV.C.3	Global LPG Demand Forecast	117
Table IV.F.1	North Sea Crude Oil Stabilization Plants	125
Table IV.L.1	Gas/Gas Liquids Processing Capacity and Production	144
Table IV.L.2	Major New NGL Recovery/Processing Projects	145

FIGURES

CHEM SYSTEMS

Figure I.B.1	Required Ethane Price vs. Gas Price	9
Figure I.D.1	Global Natural Gas Reserves	12
Figure I.D.2	Global Natural Gas Supply/Demand	13
Figure I.D.3	Reserves to Production Ratio	14
Figure I.D.4	Ethane Recovery for Feedstock Use	16
Figure II.B.1	General Natural Gas Processing Scheme	24
Figure II.B.2	Typical Phase Envelope for a Multicomponent Mixture	26
Figure II.B.3	Hydrocarbon Dew Point Limit	30
Figure II.B.4	Hydrate Formation Region	32
Figure II.B.5	Glycol Contacting Dehydration Flow Scheme	34
Figure II.B.6	Solid Adsorption Schematic	35
Figure II.B.7	Operation of Gaspipelines Transporting Large Quantities	
	of NGLs	38
Figure II.B.8	Field Processing and NGL Transport	39
Figure II.C.1	Joule Thomson Effect Shown on a Phase Diagram	41
Figure II.C.2	Simplified Joule Thomson Plant Flow Scheme	42
Figure II.C.3	Joule Thomson Plant Without Glycol Injection	43
Figure II.C.4	Joule Thomson Plant for Rich Gas With Recovery of	
	Propane and Heavier NGL Components	45
Figure II.C.5	Mechanical Refrigeration Plant Simplified Flow Scheme	46
Figure II.C.6	Inability of Mechanical Refrigeration Alone to Enter Two Phase	
	Region for NGL Extraction from High Pressure Feed Gas	48
Figure II.C.7	Turbo Expander and Joule Thomson Expansion	49
Figure II.C.8	Single Stage Turbo Expander Plant Recovery of Propane	
	and Heavier NGL Components	50
Figure II.C.9	Two Stage Turbo Expander Plant Recovery of Ethane and	
	Heavier NGL Components	52
Figure II.C.10	Bed Saturation of Single Component Being Adsorbed/Bed	
	Saturation of Multi Component Gas Stream	53

FIGURES (Continued)

Figure II.C.11	Lean Oil Absorption Plant	55
Figure II.C.12	Effect of Wellhead Pressure Decline and Remedial Measures	56
Figure II.C.13	NGL Fractionation Flowscheme	58
Figure II.D.1	Capital Costs vs. Propane Recovery	68
Figure II.D.2	Marginal Profit	77
Figure II.D.3	Extraction Profit vs. Propane Recovery	78
Figure II.D.4	Average Costs vs. Propane Recovery	84
Figure II.D.5	Required Ethane Price vs. Gas Price	88
Figure II.D.6	Required Ethane Price vs. Gas Price	89
Figure II.D.7	Required Ethane Price vs. Gas Price	90
Figure II.D.8	Required Ethane Price vs. Propane Price	91
Figure III.B.1	LFPEXOL Process for Dehydration and NGL Removal	97
Figure III.B.2	PETROFLUX Process for NGL Recovery	98
Figure III.B.3	External Cascade Refrigeration System	100
Figure III.B.4	SELEXOL Solvent Process	102
Figure III.B.5	HY-PRO Process	104
Figure III.B.6	GSP Plant Design	105
Figure IV.B.1	Sources of Natural Gas Liquids	108
Figure IV.C.1	Global Natural Gas Reserves	111
Figure IV.C.2	Global Natural Gas Supply/Demand	112
Figure IV.C.3	Reserves to Production Ratio	113
Figure IV.C.4	Ethane Recovery for Feedstock Use	115
Figure IV.D.1	United States NGL Distribution Systems	120
Figure IV.F.1	North Sea NGL Transportation Systems	126
Figure IV.H.1	NGL Gathering Facilities in Tyumen Oblast	131
Figure IV.H.2	Location of Gas Process Plants and Gas Liquids Pipelines	133
Figure IV.I.1	Location of Gas Processing Facilities in Saudi Arabia	136
Figure IV.I.2	Gas Gathering and Processing Systems in Saudi Arabia	137